ASPECTS OF *TRICHOPODA PENNIPES* (FABRICIUS) (DIPTERA:TACHINIDAE) OVIPOSITION AND ITS RELATION TO PARASITIZATION ON THE ADULTS OF *NEZARA VIRIDULA* (LINNAEUS) (HETEROPTERA:PENTATOMIDAE)[1]

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ABSTRACT - Eggs of *Trichopoda pennipes* were found on *Nezara viridula* host bodies at all sample sites. Supernumerary oviposition was found to be common on both male and female, and males had a higher incidence of tachinid eggs and more eggs/individual. Males consistently had higher parasitization levels. Tachinid eggs were found virtually on the whole body surface of *Nezara viridula*. The highest concentration was on the thorax, followed by the abdomen and head. The largest number was laid on the ventral surface of the thorax, while very few on the appendages. A significant relationship between number of tachinid eggs on the host body and level of parasitization was found. More tachinid eggs per host were directly related to a higher probability of parasitization for individuals with three eggs or less. When two tachinid eggs were present on a host, only 0.95 were truly parasitized. With three eggs or more, 0.99 were truly parasitized, and larger number of tachinid eggs on the host does not improve chances for being parasitized.

Index terms: oviposition behaviour, supernumerary oviposition, ethology of parasite.

ASPECTOS DA OVIPOSIÇÃO DE *TRICHOPODA PENNIPES* (FABRICIUS) (DIPTERA:TACHINIDAE) E SUA RELAÇÃO COM O PARASITISMO EM ADULTOS DE *NEZARA VIRIDULA* (LINNAEUS) (HETEROPTERA:PENTATOMIDAE)

RESUMO - Ovos de *Trichopoda pennipes* foram encontrados no corpo do hospedeiro *Nezara viridula* em todas as amostragens. A oviposição supernumérica foi comum em percevejos machos e fêmeas. Machos tiveram maior incidência de ovos do taquinídeo e maior número de ovos por indivíduo. Machos tiveram maiores níveis de parasitismo. Ovos do taquinídeo são, virtualmente, encontrados nas principais partes do corpo de *N. viridula*. A maior concentração foi no tórax, seguido pelo abdome e cabeça. O maior número foi na fase ventral do tórax. Poucos ovos foram depositados nos apêndices. Houve significância entre a relação do número de ovos depositados no hospedeiro e o nível de parasitismo. O número de ovos do taquinídeo por hospedeiro está diretamente relacionado à maior probabilidade de parasitismo em indivíduos com três ou menos ovos. Quando havia dois ovos no hospedeiro, somente 0,95 estavam parasitados, e com três ou mais, 0,99, sendo que isto não aumenta as chances para o parasitismo.

Termos para indexação: comportamento da oviposição, oviposição supernumérica, etologia do parasita.

INTRODUCTION

Organisms evolve in response to their changing environment, and the interaction between an exploiter and a victim is viewed as a series of coadjustments. There is a general

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tendency towards a steady state, where both species can survive (Price 1980). It is certainly not the interest of the exploiter (parasite) to exterminate the host. The interspecific relationship between *Trichopoda pennipes* and *Nezara viridula* has been studied in various levels of detail (Hokkanen 1985, 1986, Todd & Lewis 1976, Shahjahan 1968).

Shahjahan (1968) stated, based on his study of the effects of superparasitization of the southern green stink bug by *T. pennipes* that supernumerary oviposition by the parasite on the host (4-8 parasite eggs/host) seems to be desirable because only about 51% of the parasite eggs produce larvae which actually penetrate the host.

He concluded that successful penetration is affected by the location of the parasite eggs, since the larva fails to penetrate the host when eggs are deposited on the antennae, the proboscis or the wing membrane. Todd & Lewis (1976) studied natural field parasitism of adult *N. viridula* by *T. pennipes* to evaluate incidence and ovipositional patterns on eight alternate host plants. These authors showed that regardless of the host plant type, males had a higher percent of parasitization and a higher mean number of parasite eggs per bug than females. They believed that the growth habitat of various host plants had a marked effect on the overall percent parasitization of both male and female *N. viridula*. Similar results were obtained by McPherson et al. (1982), who found that significantly more *N. viridula* males had more parasite eggs on their integument and although means of 2.6 parasite eggs per male and 1.7 per female were observed, both sexes yielded a mean of 1.1 parasite larvae per host.

Correa (1984), studying egg incidence of the tachinid *Eutrichopodopsis nitens* on *N. viridula*, found that this parasite species had a higher preference for ovipositing on the thoracic region, with the highest frequency of eggs being on the prothorax (either ventrally or dorsally). An average of 3.5 and 2.9 tachinid eggs on male and female *N. viridula*, respectively.

Supernumerary oviposition by tachinid parasites on *N. viridula* was found to be common whenever it was studied for both male and female bugs. Shahjahan (1968) studied superparasitization of the southern green stink bug by *Trichopoda pennipes pillipes* in Hawaii, and concluded that superparasitization was very common under those conditions. He used the term superparasitization to describe when a female of *T. p. pillipes* oviposit on a previously parasitized southern green stink bug and more than one larva is found in a host. Under normal field conditions he found a range of 1 to 8 tachinid eggs per host but the highest number recorded was 237 eggs on a field-collected bug and 257 eggs on a laboratory-parasitized specimen. He found up to 80 dead larvae inside one host. In each case he studied that, even though many parasite larvae penetrated the host, all except one died. Michael (1981) mentioned that *T. pennipes* maggots were able to penetrate the bodies of bugs only if eggs were laid in suitable positions. However, he did not indicate which positions were suitable, but stated that only one maggot developed in each bug.

One possible indicator of the *T. pennipes* population abundance might be the number of the parasite eggs found on *N. viridula* adults. It is assumed that the higher egg number per host, the higher would be the population, since *T. pennipes* sex ratio is believed to be 1:1 (Todd & Lewis 1976, Mitchell & Mau 1971). Number of *T. pennipes* eggs on hosts would be correlated with levels of parasitization.

Harris & Todd (1981), through the mere presence of a tachinid egg on the cuticle, estimated *N. viridula* parasitization and wrongly determinated 16.8% parasitism for bugs with parasite eggs and 16.6% for bugs without eggs.

The objectives of this study were 1) to verify the incidence and oviposition pattern of *T. pennipes* on adults of the southern green stink bug collected from several host plant communities in Alaucha Co., Florida (USA), during 1986 and 1987, and to identify various parts

of the host body where eggs, once deposited, may fail to develop a truly parasitized bug, 2) to test the hypothesis that the higher the number of tachinid eggs on a host, the higher the parasitization, and 3) to estimate field parasitization by the number of tachinid eggs present on *N. viridula* adults.

MATERIALS AND METHODS

Some of the adults of *N. viridula* collected from several host plant communities in Alaucha, Co., FL, were randomly selected for this study. There was no special collection procedure, but adults were collected whenever possible during the two years of the study. Collection of adults over a long period of time assured a larger and more representative variation of the bugs observed in the period.

In an attempt to locate area(s) on the host body surface that were more or less susceptible to penetration by the tachinid larva, distribution of tachinid eggs was studied. All tachinid eggs present on the body surface of each bug were mapped on a dorsal and ventral diagram of the adult. When only one or two eggs were present, they were removed to verify the presence of the larval penetration hole under the egg. Sex, total number of tachinid eggs and effective parasitization were recorded for each bug.

For analysis of the oviposition pattern, the *N. viridula* adult body surface was divided into 19 "regions", summarized as follows: 1) antennae, 2) rostrum, 3) eyes, 4) ventral surface of the head, 5) total dorsal surface of the head, and 6) total head, 7) prolegs, 8) mesolegs, 9) metalegs, 10) total ventral thoracic surface, 11) total dorsal thoracic surface, 12) total thorax, 13) scuttelum, 14) corium, 15) wing membrane, 16) under-corium or membrane, 17) total ventral abdominal surface, 18) total dorsal abdominal surface, and 19) total abdomen.

To examine the feasibility of estimating *T. pennipes* parasitization in the field through the presence of its eggs on the host body, visual observations of *N. viridula* adults found in a soybean field were made in 1986, from August 4 to September 19. These insects were collected, sexed, and the presence of tachinid eggs on the body surface was recorded, and the insects were left in the same area in the field.

RESULTS AND DISCUSSION

Tachinid eggs on *N. viridula* adults were consistently observed during the entire study period, in both years. One hundred and fifty samples were taken from 22 different sites during 1986 and 1987, covering a period from March to October, and in all of samples of *N. viridula*, most adults had tachinid eggs. The incidence of tachinid eggs on adults, including the maximum number of tachinid eggs found per female and male host in each site, the mean number of eggs per adult and the standard deviation of the mean number of tachinid eggs were recorded (Table 1).

In 21 of the 22 sites sampled, *N. viridula* males had higher mean numbers of tachinid eggs per individual than females and one site

TABLE 1. Summary of the incidence of tachinid eggs on *N. viridula* adults collected on sampled host plant communities during 1966 and 1987.

Site	Total pop[1]	Females			Males		
		range[2]	mean[2]	SD[2]	range	mean	SD
1	184	20	5.1	4.1	43	7.6	7.1
2	15	3	2.5	.6	5	3.5	2.1
3	98	11	3.5	2.9	10	6.1	2.4
4	70	19	5.1	5.2	24	5.2	4.8
5	91	8	3.2	2.0	23	8.1	6.1
6	91	8	2.1	1.4	11	3.0	3.0
7	58	8	2.1	1.6	12	1.9	2.5
8	77	11	4.3	4.1	14	4.2	3.4
9	231	15	2.7	2.0	32	7.0	4.5
10	280	12	2.7	1.8	25	4.1	3.4
11	725	6	1.6	.9	13	2.5	1.8
12	590	12	2.8	1.7	35	4.4	3.8
13	141	15	2.1	1.5	35	9.8	6.9
14	114	13	3.8	2.2	23	9.0	5.7
15	71	14	2.9	2.1	29	13.3	8.4
16	158	6	2.2	1.2	5	1.4	6.6
17	203	29	2.4	1.8	32	7.4	6.4
18	141	13	3.3	2.7	21	6.7	5.4
19	55	9	3.2	3.4	7	3.1	1.8
20	64	2	1.1	2.5	6	2.8	1.4
21	245	5	2.4	1.3	8	2.9	1.8
22	195	6	1.9	1.3	6	2.1	1.3

[1] Total population (females and males) evaluated.
[2] Range (max. number of tachinid eggs/individual); mean and standard deviation of the evaluated population.

had equal means. This indicates that males have a higher incidence of tachinid eggs on their body surface and also a higher maximum number of eggs on their bodies. Also males had higher standard deviation values suggesting a broader variation of number of tachinid eggs on their bodies (Table 1).

Harris & Todd (1980) stated that sex ratio of *N. viridula* in the field was essentially 1:1, but they called attention to the fact that different parasitization levels between sexes may change this figure throughout the year. This was observed during both years. Always, a higher number of females was sampled, regardless of host plant and time of sampling.

During 1986 and 1987, 3959 *N. viridula* adults were collected from host plant communities studied, and 2466 (62.2%) were females and 1493 (37.8%) were males. From this total number of *N. viridula* adults collected, 649 insects, 324 males (49.9%) and 325 females (50.1%), were used to describe tachinid eggs distribution.

Tachinid eggs were found on virtually all *N. viridula* body surface examined (Table 2). The highest concentration of tachinid eggs was on the thorax, with 1596 eggs (51.6%), followed by the abdomen with 1208 eggs (39.1%) and the head with 288 eggs (9.7%). The largest number of tachinid eggs were laid on the ventral surface of the thorax, 1103 eggs, representing 69.1% of all eggs laid on the thorax. The odoriferous orifices are located there and probably account for such tachinid egg concentration. Mitchell & Mau (1971) suggested that males produce a pheromone (or another substance) that is highly attractive to the female tachinid. *T. pennipes* is a parasite that locates hosts by long-range chemoreaction (Mitchell & Mau 1971). This statement is repeatedly found in the literature, however, no reference was found that clearly mentioned scent glands as the organs responsible for releasing a substance attractive to female *T. pennipes*, but these data may suggest such a possibility.

Only 83 eggs (2.7%) were found on the appendages. It is very interesting that 347 eggs were laid on the hemelytra, and 98 of these were under or between the membranous parts of the wings. It seems almost impossible for a female tachinid to lay eggs in this particular location. Eggs were also found under the corium.

Among adults with only one or two eggs, 43 (6.6%) were not truly parasitized (35 had one egg and 8 had two eggs). No particular position indicated an overwhelmingly higher resistance to maggot penetration. If such resistance exists, the pronotum (especially the proepisternum, mesosternum and mesepisternum) seems to offer the best possibility. Evidence of this possible resistance was observed on 12 occasions when insects with egg(s) on these areas were found and entrance holes were not present and therefore bugs were not truly parasitized. The maggot is able to penetrate into the host body without making a hole in the cuticle. Evidence of this was seen several times when a tachinid egg was found

TABLE 2. Number and distribution of tachinid eggs on *N. viridula* body surface parts. Head, categories 1-6; thorax, categories 7-12; abdomen, categories 13-19.

Category	Total	Percent	Range	Mean	SD
1	2	7.0	1	0.00	0.06
2	4	1.4	1	0.00	0.08
3	70	24.3	2	0.11	0.35
4	39	13.5	2	0.06	0.26
5	173	60.1	5	0.27	0.59
6	288	9.7	-	-	-
7	37	2.3	2	0.06	0.24
8	22	1.4	2	0.03	0.20
9	18	1.1	2	0.03	0.18
10	1103	69.1	2	11.70	2.21
11	416	26.1	7	0.64	1.00
12	1596	51.6	-	-	-
13	107	8.8	11	0.16	0.60
14	175	14.5	5	0.27	0.61
15	74	6.1	2	0.10	0.33
16	98	8.1	5	0.15	0.45
17	398	32.4	11	0.61	0.99
18	33	29.5	12	0.55	0.98
19	1208	39.1	-	-	-

hatched, the host was parasitized and yet no maggot entrance hole was observed. Membranes (between sclerites) are a potential area for maggot penetration. It was observed that the larva enters the host body cavity through the hollowed podites, either the femur or tibia. A considerable number of eggs were laid on the eyes (70 eggs, 24.3% of eggs laid on the head).

To examine a relationship between number of tachinid eggs on host body and level of parasitization, a simple regression was used in data collected from 6 host plant communities (cowpea, cowpea mix, corn, cabbage, wheat and lupine).

There were significant relationships ($P < 0.05$) between number of tachinid eggs and host parasitization for some host plants, such as corn and wheat where significance occurred for both sexes. In the cowpea and lupine host plant communities theres were no significant differences between these parameters. In cowpea mix, the relationship was significant only for females but at a low level (R^2 0.16). In cabbage the relationship was significant only for males (Table 3).

The regression equations and coefficient of determination (R2 values) for crops and sex where the R2 was higher than 0.50 and are showed in Fig. 1.

The data presented by Harris & Todd (1981) about field estimation of *T. pennipes* parasitization based on its egg presence on host body was examined during 1986 soybean season. Data collected in Georgia (USA) can only be roughly compared to these data because in Georgia many more observations were male during several years.

A total of 325 *N. viridula* adults were observed, and 227 had tachinid eggs on their

TABLE 3. Coefficient of determination (R^2) between number of tachinid eggs and mean percent parasitization for female and male *N. viridula* on several host plants.

Host	Female	Male
Cowpeamix	0.16	NS
Cowpea	NS	NS
Cabbage	NS	0.52
Corn	0.42	0.46
Wheat	0.52	0.60
Lupine	NS	NS

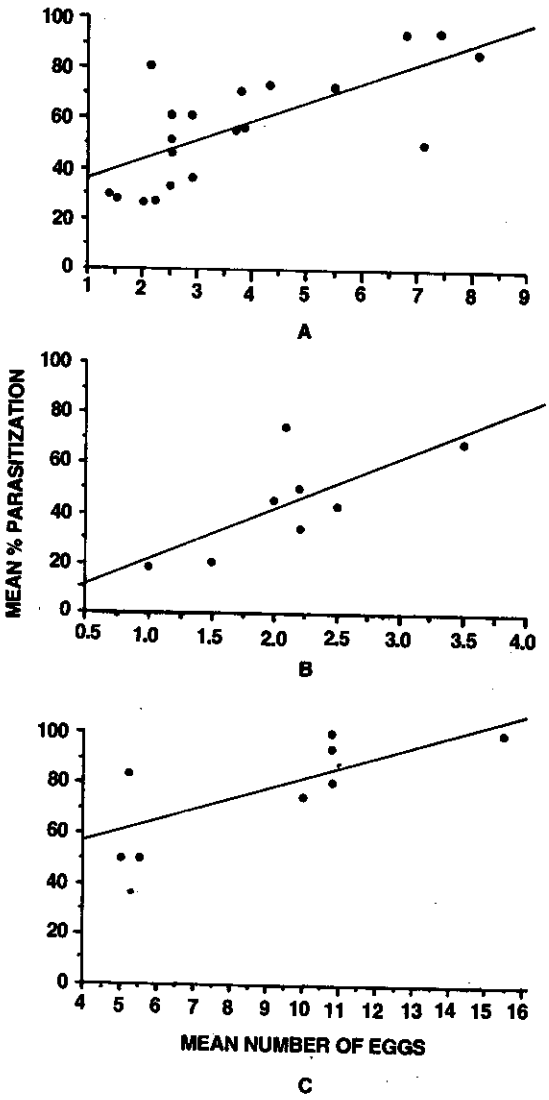

FIG. 1. Correlation between number of tachinid eggs on host body and parasitization levels. a) cabbage, males; b) wheat, female; c) wheat, male.

body surface, representing an average of 69.8% (75.3% males and 68.1% females). This estimated percentage of "parasitization" was compared to that obtained through dissection of collected adults during the same period; the latter estimate was 62.4% (55.1% males and 69.8% females). The difference is 7.4% between the two methods for determining parasitization. This is not close to the 16.8% observed by Harris & Todd (1981). However, it is important to determine a factor to correct such estimates. Obviously, this goal will be achieved only through an exhaustive research effort and is still to be done. Field estimation of *N. viridula* adult parasitization by the presence of tachinid eggs would be very valuable because it could be incorporated into the threshold level of *N. viridula* in soybeans. Currently, most, if not all, threshold levels are a mean of bugs per 3 row ft, regardless of any parasitism or parasitization value.

CONCLUSIONS

1. Tachinid egg distribution was found virtually on the entire body surface of the host.

2. The highest concentration was on the thorax, followed by the abdomen and head.

3. The largest number of eggs was laid on the ventral surface of the thorax.

4. The hypothesis that the more tachinid eggs per host was directly related to a higher probability of parasitization was found to be true for individuals with 3 eggs or less.

5. Males had higher mean numbers of tachinid eggs per individual than females.

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